Regional Operational Plan SF.3A.2014.03

Operational Plan: Interior Lake Evaluations

by

Cal Skaugstad,

and

April Behr

January 2015

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	\$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$log_{2,}$ etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

REGIONAL OPERATIONAL PLAN SF.3F.2014.03

OPERATIONAL PLAN: INTERIOR LAKE EVALUATIONS

by

Cal Skaugstad

and

April Behr

Alaska Department of Fish and Game, Sport Fish Division, Fairbanks

Alaska Department of Fish and Game
Sport Fish Division

January 2015

The Regional Operational Plan Series was established in 2012 to archive and provide public access to operational plans for fisheries projects of the Divisions of Commercial Fisheries and Sport Fish, as per joint-divisional Operational Planning Policy. Documents in this series are planning documents that may contain raw data, preliminary data analyses and results, and describe operational aspects of fisheries projects that may not actually be implemented. All documents in this series are subject to a technical review process and receive varying degrees of regional, divisional, and biometric approval, but do not generally receive editorial review. Results from the implementation of the operational plan described in this series may be subsequently finalized and published in a different department reporting series or in the formal literature. Please contact the author if you have any questions regarding the information provided in this plan. Regional Operational Plans are available on the Internet at: http://www.adfg.alaska.gov/sf/publications/

Cal Skaugstad and April Behr,
Alaska Department of Fish and Game, Sport Fish Division,
1300 College Road
Fairbanks, AK 99701

This document should be cited as:
Skaugstad, C., and A. Behr. 2014. Operational plan: Interior lake evaluations. Alaska Department of Fish and Game, Division of Sport Fish, Regional Operational Plan ROP.SF.3F.2014.03, Anchorage.

SIGNATURE PAGE

Project Title:	Interior Lake Evaluations
Project leader(s):	*Cal Skaugstad and April Behr*
Division, Region, and Area	*Sport Fish, Region III, Fairbanks*
Project Nomenclature:	Federal Aid (F-10-30; E-3-01); SWG (T-10-7); and RSA from DOT
Period Covered	1 March 2014–30 April 2015
Field Dates:	1 March–15 November 2014
Plan Type:	Category II

Approval

Title	Name	Signature	Date
Project leader	Cal Skaugstad		
Project Leader	April Behr		
Biometrician	Jiaqi Huang		
Research Coordinator	Matthew Evenson		1/27/15
Regional Supervisor	Don Roach	Don Roach	1-27-15

TABLE OF CONTENTS

Page

LIST OF TABLES iii

LIST OF FIGURES iii

LIST OF APPENDICES iii

ABSTRACT 1

PURPOSE 1

BACKGROUND 1

Stocked Fishery Evaluations 1

- Stocked Fisheries Management Plan 1
- Future Stocked Fisheries Program Assessment 2
- Current Stocked Fish Population Assessments 2
- Information Needs 3
- Lake Selection 4

New Lake Evaluations (SWG)/Ambler Road Lake Surveys (DOT) 4

- Information Needs 5
- Lake Selection 5

OBJECTIVES 11

Population Length-Age Structure 11

Basic Population Information 11

Water Quality 11

Bathymetric Data and Other Lake Characteristics 11

METHODS 11

Population Length-Age Structure 11

- Study Design 11
- Data Collection 13
- Data Reduction 14
- Data Analysis 14

Basic Population Information 15

- Study Design 15
- Data Collection 16
- Data Reduction 16
- Data Analysis 16

Water Quality 16

- Study Design 16
- Data Collection 17
- Data Reduction and Analysis 17

Bathymetric Maps and other Lake Characteristics 18

- Study Design 18
- Data Collection 18
- Data Reduction and Map Generation 19

SCHEDULE AND DELIVERABLES 20

RESPONSIBILITIES 21

REFERENCE CITED 22

APPENDICIES 24

LIST OF TABLES

Table **Page**

1. Lake description and data requirements for 2014 lake sampling. Stocked Fisheries Program (SFP), State Wildlife Grant (SWG), and Ambler Road Lake Surveys (DOT) assessment in 2014. 6
2. Sampling effort according to lake size. 12
3. Minimum sample size required to estimate mean length in a defined length group of rainbow trout in study lakes. 13
4. Descriptions of water color. 17
5. Power of Kolmogorov-Smirnov (K-S) test to detect capture heterogeneity in small populations during two-sample mark-recapture studies designed to estimate true abundance within 20% of the true value 95% of the time, where ***x***% of the population has 50% of the capture probability of the remainder of the population during both sampling events. Results based on 10,000 simulations of two age classes of fish with adjacent but non-overlapping bell shaped length distributions and ***x***% represents one entire age class. 40
6. Power of Kolmogorov-Smirnov (K-S) test to detect capture heterogeneity in small populations during two-sample mark-recapture studies designed to estimate true abundance within 20% of the true value 95% of the time, where ***x***% of the population has 50% of the capture probability of the remainder of the population during first event sampling and no capture heterogeneity occurs during second event sampling. Results based on 10,000 simulations of two age classes of fish with adjacent but non-overlapping bell shaped length distributions and *x*% represents one entire age class. 41

LIST OF FIGURES

Figure **Page**

1. Location of Lower Tanana River Management Area lakes (near Fairbanks) to be sampled in 2014. 7
2. Location of Upper Tanana River Management Area lakes (near Delta) to be sampled in 2014. 8
3. Location of Upper Copper Upper Susitna River Management Area lakes (near Glennallen) to be sampled in 2014. 9
4. Location of Yukon River and Northwest Management Area lakes to be sampled in 2014. 10
5. Shore and circular transect pattern used to collect depth data in study lakes. 19

LIST OF APPENDICES

Appendix **Page**

A. Fish population structures based on management stocking schemes. 25
B. Stocking history (2008–2013) for lakes to be sampled in 2014. 29
C. Field data forms. 32
D. Assumptions and bias. 36

ABSTRACT

The Alaska Department of Fish and Game (ADF&G) Division of Sport Fish conducts lake evaluations on both stocked and wild systems throughout Region III. Lakes to be sampled during the 2014 field season fall into three categories (with three separate funding sources): *Stocked Fishery Evaluations* (Federal Aid-FA), *New Lake Evaluations* (State Wildlife Grant-SWG), and *Ambler Road Lake Surveys* (Alaska Department of Transportation-DOT). The study design and methods used to evaluate lakes in each of these categories are similar and therefore summarized in one Operational Plan. Fish population, water quality, and bathymetric data will be collected.

Stocked Fishery Evaluations are needed to evaluate and adjust current stocking strategies and fish hatchery production, update informational handouts, and provide the public with up to date information regarding fishing opportunities.

New Lake Evaluations and *Ambler Road Lake Surveys* are needed to identify new sport fishing opportunities and to collect baseline information on water bodies with limited or no existing information. Managers need baseline information to develop management plans, assess the impacts of current or proposed development, issue permits, and monitor changes in aquatic systems over time.

Results from these monitoring projects will be made available to managers and anglers in a Fishery Data Series (FDS) report containing 2014–2016 data. The department also disseminates this information through publications such as the *Guide to Stocked Fisheries*, through the Fish and Game internet website, the Alaska Lake Database (ALDAT), and in informational handouts.

Key words: fish population monitoring, rainbow trout, *Oncorhynchus mykiss*, population structure, stocking evaluation, stock assessment, stocking method, stocking strategy, length-at-age, regional management objective.

PURPOSE

This project is an ongoing, annual effort to evaluate the lake fisheries within the Tanana and Upper Copper/Upper Susitna management areas stocked with fish raised in the Ruth Burnett Sport Fish Hatchery in Fairbanks and the William Jack Hernandez Sport Fish Hatchery in Anchorage. The objectives of the study are to determine if stocked populations are achieving desired management length and age structures; to provide fishery managers and anglers with current information about fish species present, size range, overall appearance and condition, and to document whether fish survived winter in the selected lakes; and, to describe select physical and chemical properties of the lakes already stocked as well as lakes that are candidates for future stocking.

BACKGROUND

STOCKED FISHERY EVALUATIONS

Stocked Fisheries Management Plan

In 2004, the Board of Fisheries (BOF) adopted two new general management plans for stocked fisheries within Region III (5 AAC 70.065 and 5 AAC 52.065, 2004). The plans outline three management approaches with corresponding objectives and regulations.

- Regional Management Approach. Under the regional management approach, stocked fisheries will be managed so that there will be a reasonable expectation of high catch rates and harvesting a daily bag limit. The bag and possession limit is 10 fish in combination of all stocked species, and only one of those fish may be 18 inches (457 mm TL) or greater in length. The fishing season is open year round and bait may be used.

- Conservative Management Approach. Under the conservative management approach, stocked fisheries will be managed so that there will be a reasonable expectation to catch a daily bag limit with a reasonable chance of catching fish 18 inches (457 mm TL) or greater in length. The bag and possession limit is five fish in combination of all stocked species, and only one of those fish may be 18 inches (457 mm TL) or greater in length. The fishing season is open year round and bait may be used.
- Special Management Approach. Under the special management approach, stocked fisheries will be managed so that there will be a high probability of an angler catching more than one fish a day that is 18 inches (457 mm TL) or greater in length. When considering a proposal regarding this management approach, the board should consider taking the following actions:

  (1) limit fishing to

    (A) catch-and-release fishing;

    (B) fly fishing;

    (C) trophy fishing, which means that a fish retained must be 18 inches or greater in length;

  (2) establish seasonal periods when fishing is closed or is restricted to catch-and-release fishing; or,

  (3) establish a bag limit of one fish, 18 inches (457 mm TL) or greater in length, or another appropriate bag and size (length) limit.

Future Stocked Fisheries Program Assessment

In order to more directly assess the objectives outlined in the stocked fisheries management plan, ADF&G needs to focus on anglers to assess their understanding of the three management approaches, to quantify their expectations and desires, and to determine whether these expectations are being met. This work should be conducted statewide after the Ruth Burnett Sport Fish Hatchery in Fairbanks and the William Jack Hernandez Sport Fish Hatchery in Anchorage are producing fish at a preferred stocking capacity (size and number of fish) and after the stocked fish populations have stabilized. In recent years, ADF&G has stocked fish at levels that are less than desirable and fishery managers have been faced with fluctuating numbers of fish, sizes, and production schedules that do not meet angler needs. Any efforts to survey anglers now will only serve to evaluate a changing interim condition. But, it is prudent to begin planning such a survey now.

Until hatchery production improves, and stocked fish populations stabilize, we use an indirect (but reasonable) evaluation method to evaluate specific stocked fish populations in the Tanana River Management Area (TRMA) and Upper Copper Upper Susitna Management Area (UCUSMA). These methods are outlined below.

Current Stocked Fish Population Assessments

Management Objectives and Standards

Each management approach lists general objectives for numbers and sizes of fish that anglers should have a reasonable expectation to catch and harvest. To meet these objectives we designed population structures (Skaugstad *In prep*) and implemented stocking schemes that we expect will provide a reasonable opportunity for an angler to catch and harvest the number and size of fish described in each approach.

From these population structures we determined standards for each management approach by calculating the mean length for the portion of the population structure within an appropriate size group (Appendix A). For a fishery to be considered a success the observed mean must equal or exceed the standard.

Information Needs

Fish Populations

Fishery managers have identified two levels of sampling to obtain fish population information needed to periodically evaluate stocked fisheries and determine if reasonable opportunity is being provided. The first level requires unbiased length information to determine if stocking strategies have created the desired population structures, which typically have been defined for most rainbow trout populations. This information is obtained using sampling methods that are described in the *Population Length-Age Structure* section of this plan.

The second level requires only basic information about the presence, size range, and general health of fish populations to determine if objectives are met. This information is collected using sampling methods to observe fish populations in several lakes each year, to determine if fish survived winter, and to make a general assessment of a population's overall status. Sampling methods used to acquire this information are described in the section *Basic Population Information*.

Fishery managers will use the information from both levels of sampling to adjust stocking methods and fish hatchery production. After examining the information, managers may decide that more accurate and detailed research on fish populations or habitat is warranted.

Water Quality

Water quality data are needed to help biologists and managers determine stocking strategies and interpret sample results.

We use parameters such as temperature and dissolved oxygen to select suitable species for stocking and to determine the size and number of fish to stock. Because different species have different thermal tolerances and habitat niches the data we collect helps us identify available habitat and then select the species that is best suited for that environment.

We also use water quality data to help us interpret why a population length-age structure does not conform to our expectation. Water quality parameters can influence fish growth and abundance of prey, consequently influencing survival and the population's length-age structure. By examining a population length-age structure and using ancillary information about water quality, we can often identify likely explanations for differences between the actual and desired length-age structures. Managers and biologists can then make informed and suitable adjustments to the stocking scheme. Occasionally, we may discover that for some lakes the desired population structure is not realistic due to the natural limitations of the system.

Bathymetric Maps

Bathymetric maps are used to describe a lake's physical characteristics. A bathymetric map is used to calculate several characteristics such as surface area, maximum length and width, mean depth, maximum depth, shoreline length, shoreline development, and volume that are crucial to understanding how a lake system functions. The shape and structure of a lake basin strongly influences the lake's biotic and abiotic characteristics. We use a lake's morphometric features, in combination with other limnology features such as prevalence of aquatic vegetation, to predict seasonal thermal and dissolved oxygen profiles and the likelihood of winter-kill events. We use this information to select suitable species and methods for stocking fish.

Lake Selection

Currently, there are 111 lakes in the Stocked Fisheries Program (SFP) in Interior Alaska. This number fluctuates annually as lakes are added to or removed from the program. Because research and management resources are limited, only 10 to 20 lakes can be examined each year.

The criteria for selecting lakes for study include: 1) the importance of the information for management needs; 2) the number of public inquiries or requests for development of a fishery, or for information about the lake or species present in the lake; and, 3) the desire to visit most stocked lakes at least once every 5–10 years to assess fish populations and lake habitat.

Fish populations in 11 stocked lakes in the TRMA and UCUSMA will be examined during the 2014 field season (Table 1, Figure 1–3); all lakes are in the Regional Management category. Basic population information is needed for fish populations in eight study lakes and length-age information is needed for populations in three lakes (Table 1). Desired population structures used to perform length-age analysis are shown in Appendix A. Water quality data will be collected on all 11 lakes (Table 1). Lake locations are shown in Figure 1–3 and recent stocking histories for each lake are listed in Appendix B.

NEW LAKE EVALUATIONS (SWG)/AMBLER ROAD LAKE SURVEYS (DOT)

These projects are designed to collect baseline information about the current status of aquatic communities and habitat throughout Alaska over time. The information needed for new lake evaluations is nearly identical to that which is collected during *Current Stocked Fish Population Assessments*. We will collect data to determine fish species present, evaluate water quality, and create bathymetric maps.

For many lakes in Interior Alaska species and habitats have not been investigated, documented, or, in some cases, sampled in over 50 years. Some of these aquatic systems are in areas that are or will be impacted by current and proposed resource exploration and development. Exploration and development activities include the extension of the Alaska railroad, proposed roads, resource extraction, and more extensive and intensive use of military training areas. Resource managers need a better understanding of the distribution and habitat use of freshwater fishes within Interior Alaska in order to maintain healthy aquatic resources that will sustain responsible use and development.

Fish information, water quality, and bathymetry data are used by state and federal agencies when developing management plans, assessing the impacts of current or proposed development, issuing permits, and monitoring changes in aquatic systems over time. From these observations managers can judge if natural or human activity is resulting in changes to fish distribution, size, abundance, and community structure. In addition to documenting species and habitat, these sampling actives will also help ADF&G Sport Fish area managers identify new angling opportunities.

Information Needs

Fish Populations

Basic population information is needed to document native species present, their size range, and their overall condition. This information helps biologists and managers identify critical habitats, fish distributions, the current status of fish communities, and fish populations that require more detailed investigation. Fish presence information is also needed to address public stocking requests and inquiries about wild systems and angling opportunities. Sampling methods used to acquire this information are described in the section *Basic Population Information*.

Water Quality

Water quality data is needed to identify the types and limits of habitat used by different fish species, to document baseline levels, to monitor habitat changes over time, and to plan more detailed fish or habitat research. Water quality information such as dissolved oxygen and temperature is useful when evaluating fish species presence or absence and is used to establish fish sampling protocol such as appropriate capture gear and sample locations.

Bathymetric Maps

Bathymetric maps are used to calculate several characteristics such as surface area, maximum length and width, mean depth, maximum depth, shoreline length, shoreline development, and volume. These characteristics are also useful when identifying habitat needs, usage, and limitations. Documentation of the physical attributes of a lake (e.g., surface hectares) can be used to monitor environmental changes, such as lake succession, declining water level, and identifying attributes (e.g., deep vs. shallow) that may limit fish presence or habitat. Additionally, volumetric calculations from bathymetric data are often required before permits for resource use and extraction are issued.

Lake Selection

Lakes are selected for sampling at an area manger's request. Sample lakes are prioritized based on 1) the importance of the data for management needs (i.e., proposed development or to issue permits); 2) input from the public; and, 3) the available budget and associated project costs.

Five lakes have been selected for *New Lake Evaluations (SWG)* in the TRMA and UCUSMA (Table 1, Figure 1–3). Fish presence, water quality, and bathymetric data will be collected at Tanana Lake and Big D2 Lake and bathymetric data will be collected at the remaining locations as time, personnel, and budget allows.

Ten candidate lakes have been identified for *Ambler Road Lake Surveys (DOT)* in the Northwest and Yukon River Management Area (Table 1, Figure 4). Six of the 10 lakes will be sampled during the 2014 field season; fish presence, water quality, and bathymetric data will be collected.

Table 1.–Lake description and data requirements for 2014 lake sampling. Stocked Fisheries Program (SFP), State Wildlife Grant (SWG), and Ambler Road Lake Surveys (DOT) assessment in 2014.

Lake/Date	Management	Hectare (Acre)	Fish	Native	Previously	Water	Map	Project
Northwest Management Area								
Avaraart Lake	n/a	276.18 (682.4)	Basic	Unknown	-	Yes	Yes	DOT
Nutuvuki Lake	n/a	1552.51 (3836.3)	Basic	Unknown	-	Yes	Yes	DOT
Norutak Lake	n/a	1691.15 (4178.9)	Basic	Unknown	-	Yes	Yes	DOT
Kollioksak Lake	n/a	307.3 (759.4)	Basic	Unknown	-	Yes	Yes	DOT
Tanana River Management Area								
Fairbanks								
Bathing Beauty Pond	Regional	5.03 (12.4)	Basic	NP	AC, RT, KS, GR	Yes	No	SFP
Parks Hwy 261	Regional	1.62 (4.0)	Basic	None	RT	Yes	Yes	SFP
Tanana Lake	Regional	3.02 (7.5)	Basic	Unknown	-	Yes	Yes	SWG
Z Pit	Regional	2.83 (7.0)	Basic	None	GR	Yes	Yes	SFP
Delta								
Backdown Lake	Regional	2.09 (5.2)	Length-Age	None	AC, RT	Yes	No	SFP
Big D Pond	Regional	4.00 (9.77)	Basic	None	LC	Yes	No	SFP
Big D2 Pond	n/a	Unknown	Basic	Unknown	-	Yes	Yes	SWG
Donnelly Lake	Regional	12.29 (30.4)	Length-Age	SSC	RT	Yes	No	SFP
George Lake	n/a	1933.63 (4778.1)	-	-	-	-	Yes	SWG
Healy Lake	n/a	3.02 (7.46)	-	-	-	-	Yes	SWG
Jan Lake	Regional	9.20 (11.7)	Basic	None	SS, RT, GR, KS	Yes	Yes	SFP
Last Lake	Regional	1.15 (2.8)	Basic	None	AC, RT	Yes	No	SFP
Upper Copper Upper Susitina Management Area								
Seven Mile Lake	n/a	648.07 (1601.4)	-	-	-	-	Yes	SWG
Tex Smith Lake	Regional	6.30 (15.6)	Basic	None	RT, AC in 2014	Yes	No	SFP
Tolsona Mountain Lake	Regional	24.72 (61.1)	Length-Age	None	RT	Yes	No	SFP
Two Mile Lake	Regional	5.19 (12.8)	Basic	GR, SSC	RT	Yes	No	SFP
Yukon River Management Area								
AR1	n/a	18.55 (45.8)	Basic	Unknown	-	Yes	Yes	DOT
AR2	n/a	10.53 (26.0)	Basic	Unknown	-	Yes	Yes	DOT
Birch Hill Lake	n/a	30.58 (75.6)	Basic	Unknown	-	Yes	Yes	DOT
Tobuk Lake	n/a	179.8 (444.4)	Basic	Unknown	-	Yes	Yes	DOT
AR4	n/a	84.37 (208.5)	Basic	Unknown	-	Yes	Yes	DOT
AR5	n/a	38.84 (96.0)	Basic	Unknown	-	Yes	Yes	DOT

AC=Arctic char	*Salvelinus alpinus*	LNS=longnose	*Catostomus*	RWF=round	*Prosopium*
GR=Arctic grayling	*Thymallus arcticus*	LT=lake trout	*Salvelinus*	SF=Sheefish	*Stendous leucichthys*
HBWF=hump back	*Coregonus oidschian*	NP=northern pike	*Esox lucius*	SS=coho salmon	*Oncorhynchus*
KS=Chinook salmon	*Oncorhynchus*	RS=sockeye	*Oncorhynchus*	SSC=slimy	*Cottus cognatus*
LCI=Least Cisco	*Coregonus said*	RT=rainbow trout	*Oncorhynchus*		

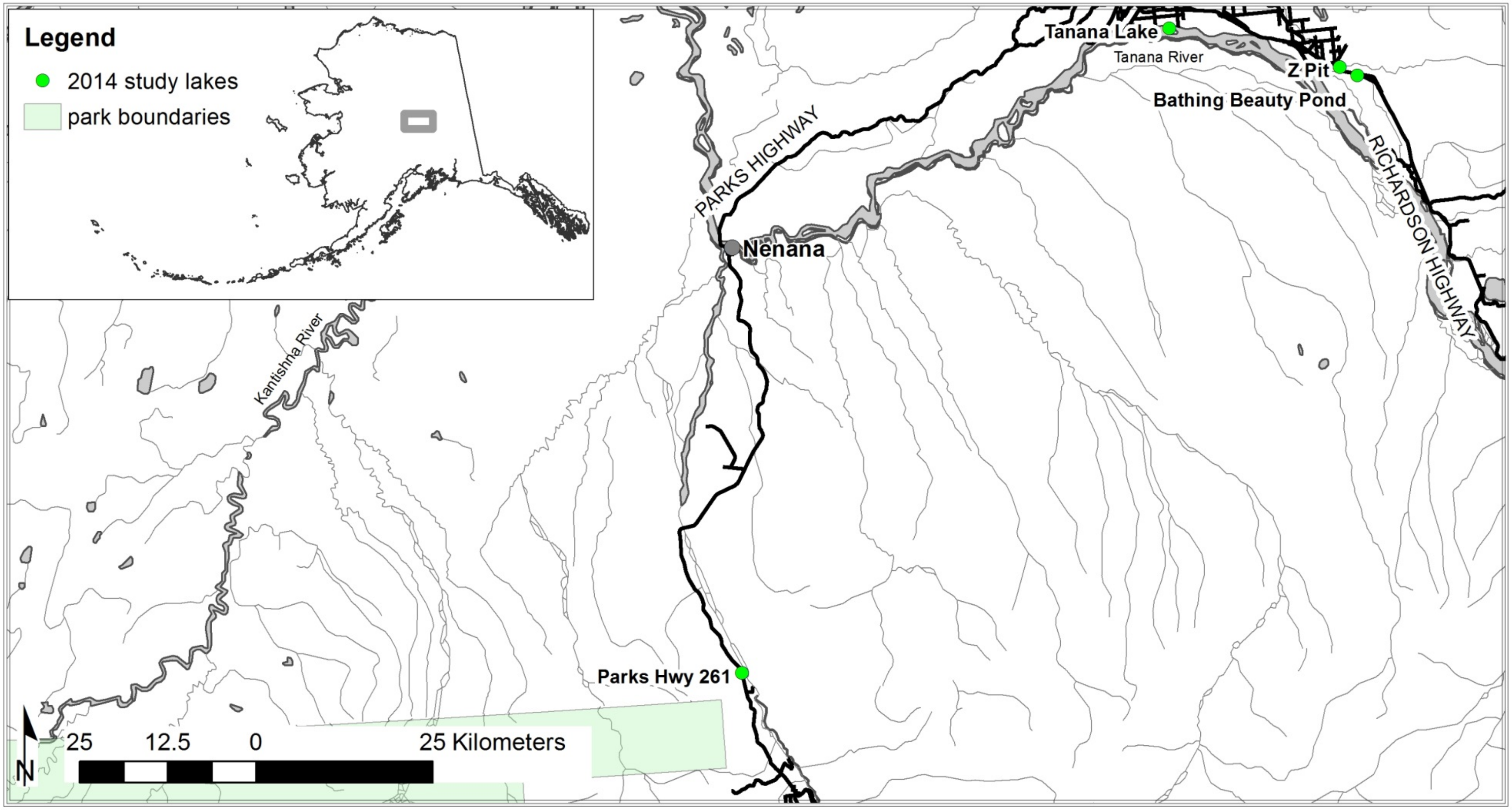


Figure 1.–Location of Lower Tanana River Management Area lakes (near Fairbanks) to be sampled in 2014.

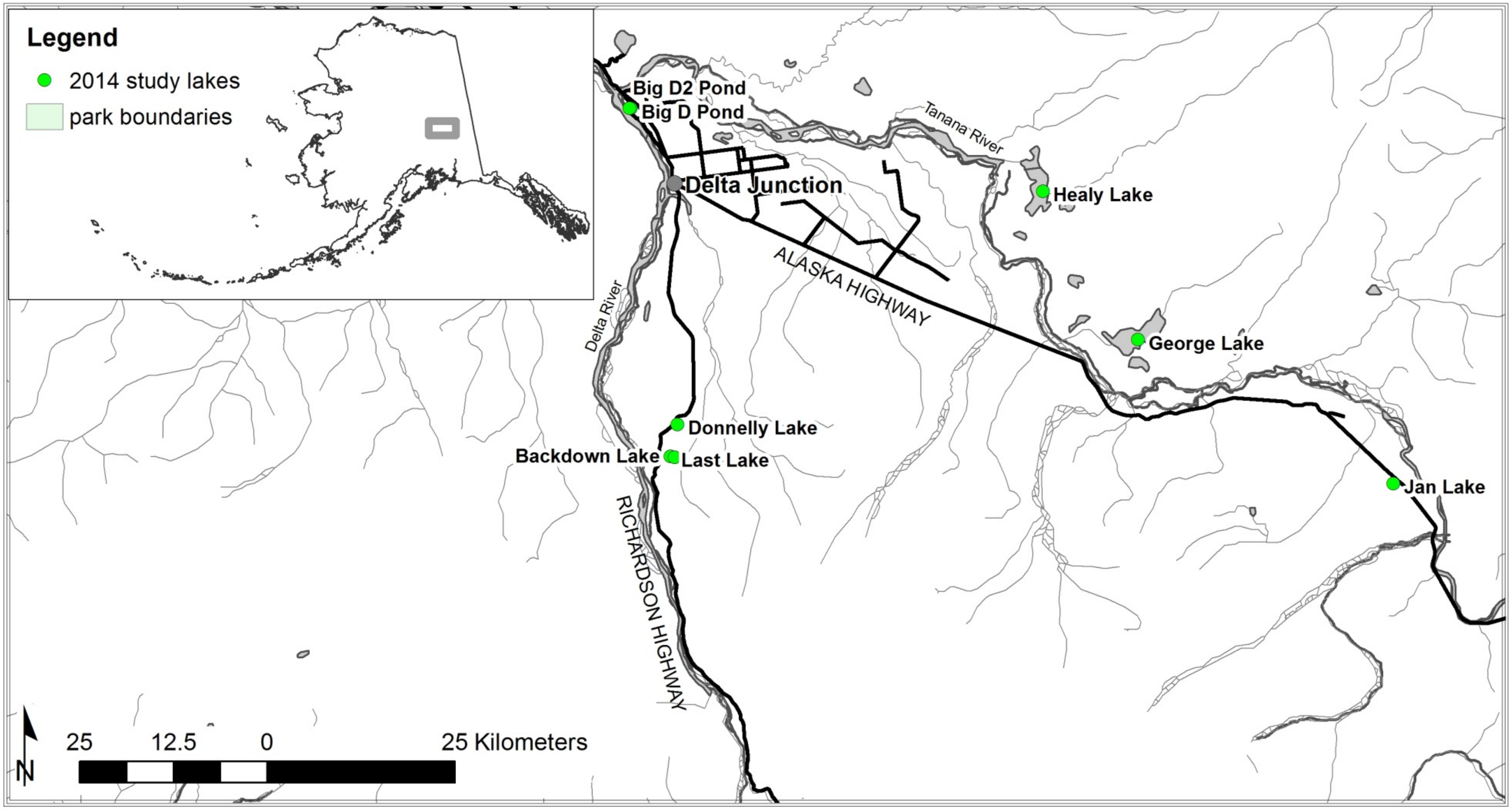


Figure 2.–Location of Upper Tanana River Management Area lakes (near Delta) to be sampled in 2014.

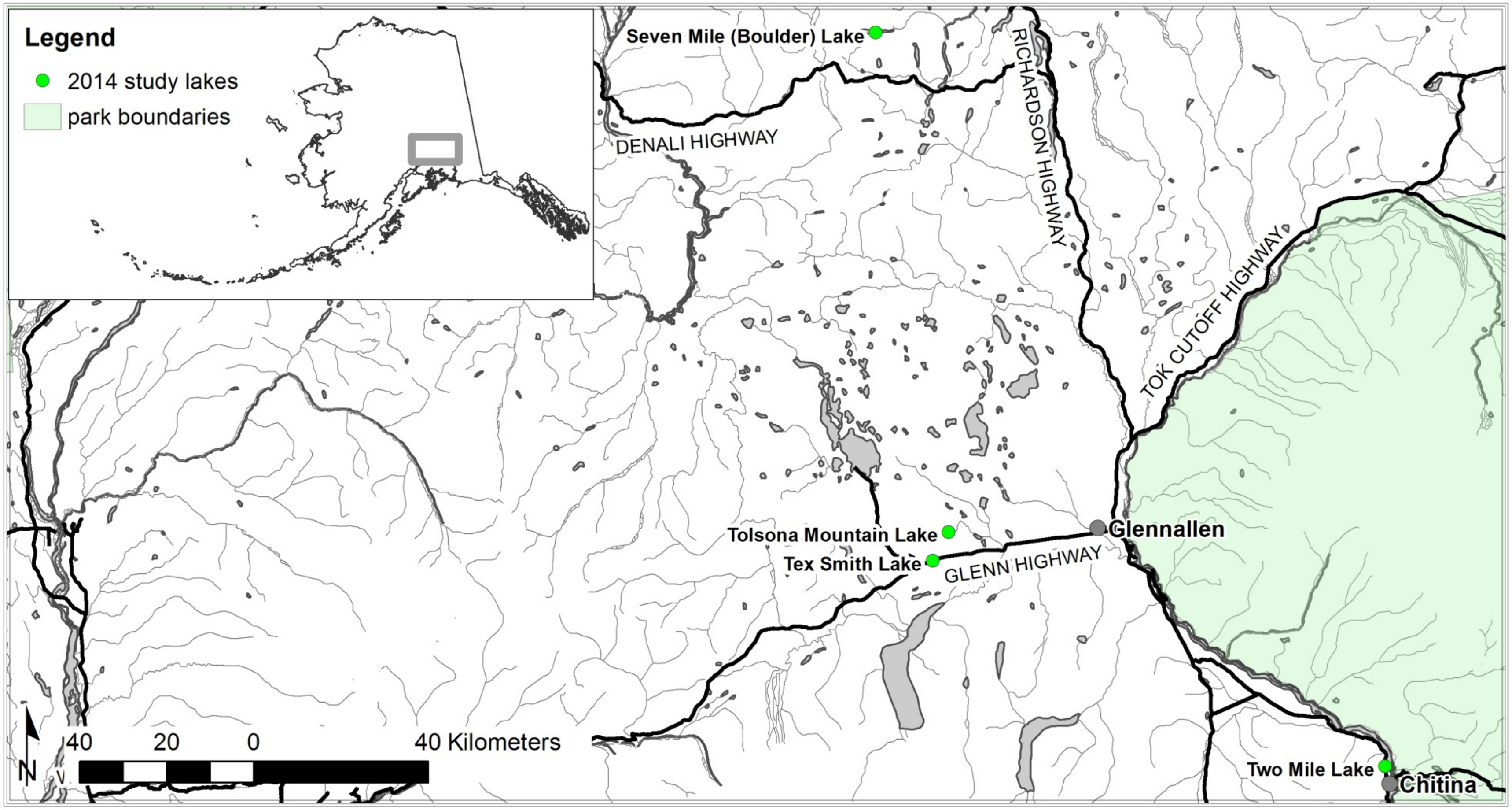


Figure 3.–Location of Upper Copper Upper Susitna River Management Area lakes (near Glennallen) to be sampled in 2014.

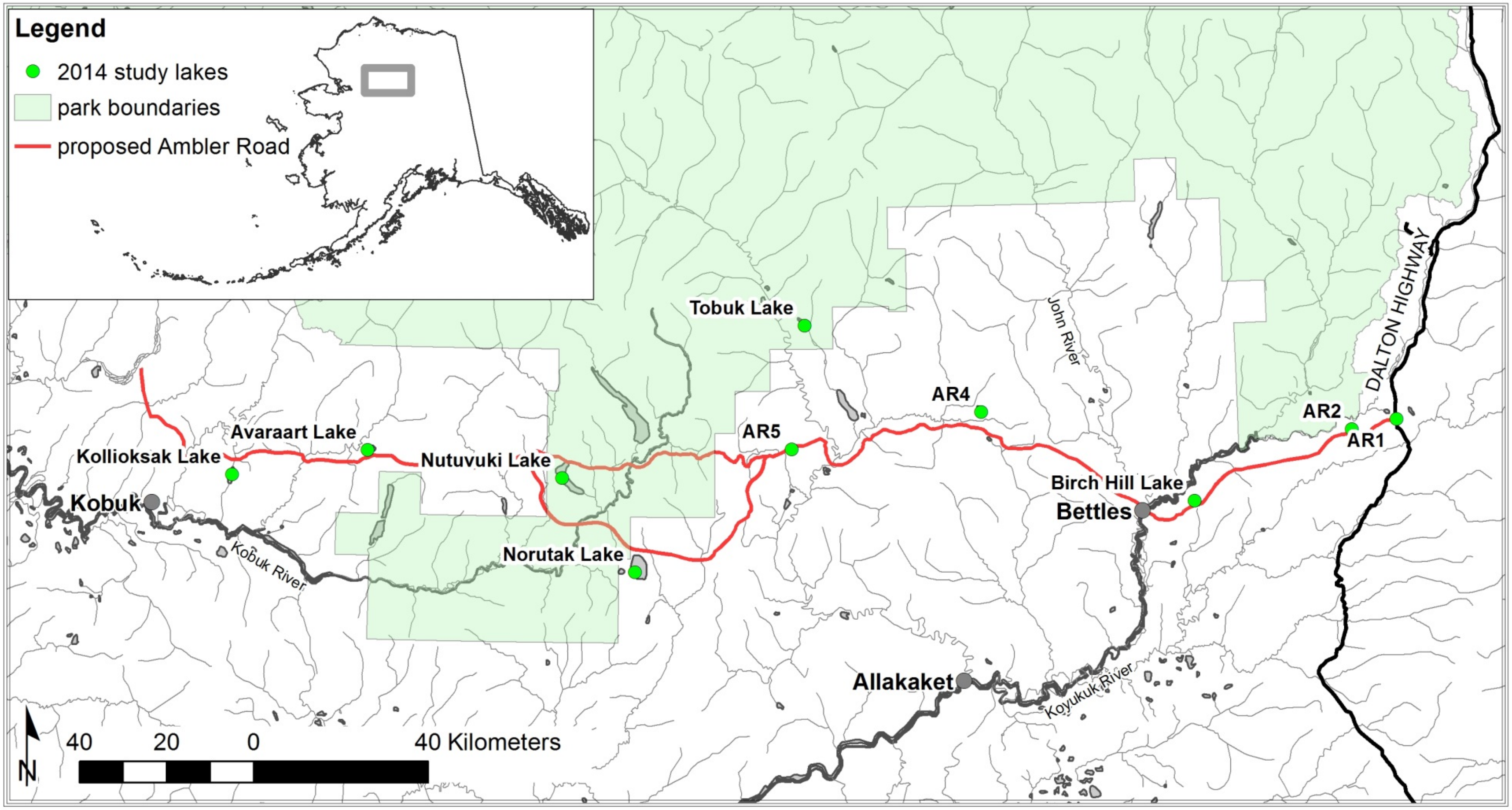


Figure 4.–Location of Yukon River and Northwest Management Area lakes to be sampled in 2014.

OBJECTIVES

Population Length-Age Structure

Management Objective 1:	Determine if rainbow trout populations are achieving the management length and age structures listed in Appendix A.
Research Objective 1:	Test the null hypothesis that mean length of rainbow trout within defined length categories (listed by fishery in Appendix A) does not differ from the management value with 90% power of rejecting the null hypothesis if the true mean length differs from the management value by more than 10% using alpha = 0.10.

Basic Population Information

Management Objective 2:	Provide fishery managers and anglers with current information about fish species present, size range, overall appearance and condition, and document whether fish survived winter in the selected lakes.
Research Objective 2:	Survey selected lakes to determine fish species present, characterize the size range of the fish captured, and describe the overall appearance and condition of captured fish.

Water Quality

Management Objective 3:	Describe select physical and chemical properties during fish sampling (June, August, or September).
Research Objective 3:	Measure water clarity, temperature, dissolved oxygen, pH, total dissolved solids, specific conductivity, and alkalinity.

Bathymetric Data and Other Lake Characteristics

Management Objective 4:	Collect morphometric data.
Research Objective 4:	Survey the lake bottom to obtain depth, longitude, and latitude data for producing bathymetric maps;
Research Objective 5:	Describe the lake watershed and the immediate surroundings, such as tree/shrub cover, and inlets and outlets; and,
Research Objective 6:	Photograph the lake and surrounding area from north and south locations and, if flown into a lake, take aerial photographs of the lake and surrounding area.

METHODS

Population Length-Age Structure

Study Design

The length-age structure of rainbow trout populations in specified stocked lakes will be estimated using single-sample capture events. The population length structure will serve as an indicator of the population age structure. Scales will not be collected for aging because hatchery reared fish often have false annuli that confound accurate aging. All sampling will be conducted when water temperature at 1 m below the surface is < 18°C.

Sampling Methods

Capture Gear

Fyke nets will be set near shore on the lake bottom in 1 m to 2 m of water. The location and spacing of the nets will be left to the crew leader's judgment. Fyke nets have square openings that are either 0.9 m or 1.2 m per side, the body length from opening to cod end is about 5 m, hoop size is 0.9 m in diameter, and mesh size is 9 mm^2. Wings measuring 7.5 m long by 1.2 m deep are attached to each side of the frame at the open end. The net body will be positioned parallel to shore and the wings will be set to form a "V". Each fyke net will be pulled taut from the cod end and held in position with a weight.

Tangle nets will be set perpendicular to shore in water deeper than 2 m and will only be used when the crew is on site to reduce injury to fish. Tangle nets measure 45 m long by 5.4 m deep and are made of 13 mm bar fine thread monofilament. Mesh size is small to ensure that fish will be captured by entanglement around the mouth and not by the gill covers. One of two types of tangle nets will be used. One net is a "floater" (the float line buoyancy is greater than the weight of the lead line); the other net is a "sinker" (the lead line is weighted to overcome the buoyancy of the float line). The floater has a triple float line and 13.6 kg lead line. The sinker has a double float line and a 31.75 kg lead line. Tangle nets will be checked every 30 minutes. The crew leader will adjust the time interval after assessing captured fish.

Sampling Schedule

The amount of capture gear and the duration of sampling projects will be based on lake size (Table 2).

Table 2.–Sampling effort according to lake size.

Hectare (Acre)	Nights	Fyke Nets	Tangle Nets	Minnow Traps[a]
0 to 20 (50)	1	4	1	4
>20 to 40 (100)	2	4	1	4
>40 to 200 (500)	3	4	2	4
>200 to 400 (1,000)	3	6	2	6
>400 (1,000)	3	8	2	6

[a]Minnow traps are not used to sample stocked lakes; however, they are used during new lake evaluations and are referenced later in this plan.

Marking

If nets are fished for more than one night, fish captured for the first time regardless of gear type will be marked by removing a half circle of tissue from the trailing edge of the upper lobe of the caudal fin. The mark will be made with a paper punch that produces a 7 mm diameter circular hole. This marking method is desired because the mark is easily recognized, the amount of removed tissue is small, and the mark usually regenerates within a year. Other marking methods that use total fin removal or Floy™ tags are permanent and diminish the appearance that anglers desire for fish when they reach larger size.

Sample Size: Hypothesis Test of Mean Lengths (Research Objective 1)

Mean lengths will be estimated within specified length groups. Minimum sample sizes to satisfy the precision criteria for Objective 1 are determined by calculating the population mean and variance by length group for each lake using the management length distributions displayed graphically in Appendix A. Minimum sample sizes for estimating mean length for each length group *g* (*g* = 1 to *G*) were calculated using (Zar 1984):

$$n_g = \frac{s_g^{\ 2}}{\delta_g^{\ 2}}\left(t_{\alpha(1,2),\upsilon} + t_{\beta,\upsilon}\right)^2 \tag{1}$$

where:

n_g is the minimum sample size for group *g*;

t are critical values from Student's t-distribution;

υ is the degrees of freedom;

s_g^2 is the population sample variance of the distribution of management lengths in *g*; and,

δ_g is the minimum detectable length difference (10%) of management lengths in *g*.

The calculated minimum sample sizes for each lake for length group *g* are shown in Table 3.

Table 3.–Minimum sample size required to estimate mean length in a defined length group of rainbow trout in study lakes.

Lake	Predicted Abundance	Sample Size (n)
Tanana River Management Area		
Backdown Lake	26	7
Donnelly Lake	130	7
Upper Copper Upper Susitina Management Area		
Tolsona Mountain Lake	872	6

The predicted abundance for each lake (Table 3) is based on a preferred stocking scheme and estimates of survival for age-1 through age-5 as described in Skaugstad (*in prep*). Typically, less than 10% of a population is handled during single-sample capture events. Proportionally more effort will be directed towards smaller populations where minimum sample size exceeds 10% of the population.

Data Collection

All data will be recorded in field notebooks or on pre-made forms (Appendix C). Prior to field work the crew leader will obtain a lake map from files or generate a map from a computer mapping application. Bathymetric markings are preferred if available. The crew leader will provide one copy for each day of field work plus two extra copies.

Every day, capture gear type (fyke nets, tangle nets, sport gear), capture gear locations (waypoint: WGS 84 ddd.ddddd), set depths (m or ft), set and pull dates (MM/DD) and times (military), and temperature (to the nearest 0.10°C) will be recorded on a data form (Appendix C). Also, a new lake map will be used each day to record capture gear type and locations.

Fish length (nearest mm FL), visual inspection of fish body appearance (thin vs. normal), and external signs of disease and parasites along with any tagging data (recapture) will be recorded on the field form as described in Appendix C.

The crew leader will also keep a detailed, daily field journal in a "Rite-in-the-Rain®" notebook. An important goal is to identify conditions that may substantially affect the probability of capture during a sampling event. Information collected should include:

1) Major weather events (rain, hail, high wind) and water conditions (waves, clarity); and,
2) Any other relevant details or observations, such as fish behavior (spawning, feeding), fish health, and note the type of aquatic invertebrates present (identify to order if possible).

Data Reduction

Data will be transferred from notebooks and field data forms to Microsoft Excel worksheets for analysis and archival. The worksheets will provide a complete history of capture and biological data for each fish. All data and descriptive information in notebooks and field data forms will be examined for obvious errors, corrected, and entered into a Microsoft Excel spreadsheet immediately following the field collection period. After entering the data into the spreadsheet, a battery of data summaries will be performed to identify obvious transcription errors (i.e., lengths smaller or larger than what was observed in the field or GPS coordinates that lie outside the lake perimeter). Errors will be corrected when possible or the data will be excluded from further analysis. Additional columns may be added for clarity and a glossary of all column headings will be provided in a text box along with a brief project description. Final copies of worksheet files will be provided with the completed report when it is submitted for printing to be archived in the Sport Fish Division Docushare repository. At that time, a file name and directory will be assigned, which will be included as an appendix in the final report. All fish data will also be stored in the Alaska Lake Database (ALDAT) accessible at:
http://www.adfg.alaska.gov/SF_Lakes/.

Data Analysis

Length Frequency Distributions

The *histogram* function in Excel will be used to count the number of rainbow trout having lengths that fall within 10 mm length categories. Length categories will start at 0 mm and increase by 10 mm intervals (e.g., 0 to <10 mm, 10 to <20 mm, etc.) The last length category for a data set will include the largest fish. This information will be used to create a column chart to illustrate the population length frequency distribution (LFD).

The histograms will be used to count the number of fish having lengths that fall within a defined length category: between ≥200 mm and <350 mm or ≥350 mm (depending on the management category of the lake). Additionally, the LFD chart will be used to visually identify length-age cohorts within the population and to help determine the mode for each cohort. For the fisheries that are stocked on alternate years the length-age cohorts can often be identified because two age cohorts are separated by a missing age cohort. However, when the fishery is stocked every year, length-age cohorts are not easily identified. Faster growing fish in a younger cohort can be larger than the slower growing fish in an older cohort. As a result, the length-age cohort LFDs overlap making it difficult to distinguish length modes and to determine the number of fish in each cohort.

Estimates of Mean Lengths

Mean lengths of fish captured and corresponding sampling variances within length categories described in Appendix A will be calculated using standard sample summary statistics (Cochran 1977).

Hypothesis Test of Management Means

The observed mean lengths from collected data will be compared to the standards for length categories (Appendix A) using a one tailed t-test (Zar 1984).

Assumptions and Bias

One potential concern with using data from this single-sample study design is that inadequate data are collected to evaluate size bias during sampling. This topic is addressed in Appendix D.

Other Biological Data

The number of fish classified as having external signs of disease, parasites, or a thin body will be summarized as follows: x/n (x number of fish were classified with the condition out of a sample size of n fish).

BASIC POPULATION INFORMATION

Study Design

This sampling procedure is designed to collect minimal but sufficient data to answer basic questions posed by fishery managers. This approach is appropriate because costs are minimized which allows a large number of fisheries to be sampled during the year.

We will use single-sample capture events to identify fish species present and to describe the length distribution and overall health of captured fish. Fyke nets and tangle nets will be used to capture fish species in stocked lakes. Fyke nets, tangle nets, and minnow traps will be used to sample fish populations in lakes that are not stocked.

Sampling Methods

Capture Gear

General descriptions and methods for using fyke nets and tangle nets are described in *Population Length-Age Structure – Sampling Methods*.

Minnow traps will be used in both near shore and offshore areas. Lake depth at each set location will be recorded. Set and pull times will be noted so that sampling effort is available. Minnow traps are 22 cm diameter and 42 cm long with an inward pointing funnel at each end. Traps are made of 6 mm wire mesh and will be attached to a vertical line that has a float on one end and a weight on the other, positioned horizontally in the water column, and baited with unsalted salmon roe or raw shrimp.

Sampling Schedule

The amount of capture gear and the duration of sampling projects will be based on lake size as outlined in the *Population Length-Age Structure* section of this plan (Table 2). The amount of capture gear may be adjusted to accommodate logistical constraints and reduce transportation costs when sampling in remote areas accessible only by aircraft.

Data Collection

The procedures described in *Population Length-Age Structure–Data Collection* will be followed.

Data Reduction

The procedures described in *Population Length-Age Structure–Data Reduction* will be followed.

Data Analysis

Sampling data will be summarized to show species present and size range (smallest and largest fish by species). LFDs plots will be generated when 10 or more fish of the same species are captured. For stocked lakes, when data are sufficient ($n \geq 15$), statistical analyses on rainbow trout will be performed following procedures describe for *Population Length-Age Structure*. Preliminary power analysis indicated that, in most cases, a sample size of 15 was sufficient to achieve our desired precision criteria.

WATER QUALITY

Study Design

Sampling will be conducted at each study lake during fish sampling (June, August, or September) and during midsummer (July) and late winter (March) if time permits. These times were selected because environmental conditions often approach critical biological limits and fish are physically stressed. Summer water temperatures normally peak in most lakes during July (LaPerriere et al. 2003a) and dissolved oxygen levels can fluctuate dramatically within the course of a single day. High temperatures and low dissolved oxygen levels approach and may possibly exceed critical limits for some game fish species.

In northern latitude lakes, increasing length of time of ice and snow cover can reduce the contribution of oxygen by photosynthetic organisms and prolong the depletion of the oxygen reservoir by decomposers (LaPerriere et al. 2003b; Horne and Goldman 1994; Wetzel 1975; Danylchuk and Tonn 2003). These conditions increase the likelihood of winterkill where fish die due to low levels of dissolved oxygen.

Sampling Methods

Physical and chemical properties will be measured at a minimum of two stations in each lake. One station will be situated at the maximum depth of each major basin present in the lake. If there is only one basin, the second station will be located equal distance between the maximum depth and nearest shore (along the long axis of the lake; Koenings et al. 1987). A *YSI Incorporated Environmental Monitoring System 600XLM Sonde* or *Hydrolab MS5 Sonde* will be used to measure temperature, pH, dissolved oxygen, percent dissolved oxygen, specific conductivity, and total dissolved solids. Methods for operating the instruments will follow procedures described in the appropriate instruction manual. A 1-L sample of lake water will be taken over the deepest basin from a depth of 0.3m (1ft) and later titrated at room temperature to determine total alkalinity. Water transparency will be measured as the average of the depths that a Secchi disk disappears and reappears as it is lowered and raised in the water (Koenings et al. 1987).

Data Collection

Lake name (location), lake type (glacial, organically stained, or clear-water), GPS coordinates, date, time, and weather conditions (e.g., cloud cover, air temperature) will be noted on a field data sheet (Appendix C). Water temperature, dissolved oxygen, percent dissolved oxygen, specific conductivity, pH, total dissolved solids, and oxidation reduction potential (ORP) readings will be recorded at 0.5 m intervals from the surface down to 5 m, and then at 1 m intervals until the lake bottom is reached. The depths where a Secchi disk disappears and reappears in the water will be recorded. Lake water color will be visually assessed in the field as clear, ferric, glacial-high turbidity, glacial-low turbidity, humic, or muddy (Table 4).

Table 4.–Descriptions of water color.

Code	Description	Definition
CLR	Clear	Transparent water, or nearly so.
FER	Ferric	Rust- (orange) stained.
GHT	Glacial, High Turbidity	High turbidity waters (visibility $\leq$ 30 cm (12 in) typical of streams originating directly from glaciers (e.g., Matanuska River).
GLT	Glacial, Low Turbidity	Low turbidity waters (visibility > 30 cm) typical of systems with large lakes (settling basins) below glacial discharge (e.g., Kenai River). These waters are frequently turquoise-colored.
HUM	Humic	Tea-colored water (tannic)
MUD	Muddy	Dark water with high suspended particulate load.

A 1-L water sample for alkalinity will be collected near the middle of the lake about 0.3 m beneath the surface immediately before leaving the lake and stored in a dark bottle and kept cool. Alkalinity samples will be refrigerated until they are analyzed in a laboratory. Prior to titration, samples will be brought to room temperature. A 100 mL sample will be titrated with sulfuric acid (0.02N) to an endpoint of pH 4.5 and the amount of titrant will be recorded (Koening et al. 1987). Each sample will be analyzed three times and the average will be the total alkalinity.

Data Reduction and Analysis

Data collected in the field and laboratory will be transferred from field data sheets and laboratory notes into computer spreadsheets for reduction, analysis, and archiving.

Graphic profiles of temperature and dissolved oxygen will be generated using Microsoft Excel. Profiles will be inspected for readings that approach or exceed the upper and lower biological limits for stocked game fish species.

Total alkalinity (mg/L as $CaCO_3$) will be calculated using the following equation (Koening et al. 1987):

$$TA = \frac{B \times N \times 50{,}000}{V} \qquad (2)$$

where:

TA is the total alkalinity (mg/L as $CaCO_3$);

B is the mL of titrant (0.02N H_2SO_4);

N is the normality of the titrant;

and,

V is the sample volume.

The Secchi disk transparency (SD) is the average of the two recorded depth readings.

Reduced data from water quality sampling will be stored at the ADF&G Region III Sport Fish office and distributed to the public upon request.

BATHYMETRIC MAPS AND OTHER LAKE CHARACTERISTICS

Study Design

Selected lakes will be surveyed for bathymetry data and peripheral watershed features, such as inlets and outlets, and the main terrestrial vegetation type surrounding the lake (tree, grass, shrub). For lakes that have bathymetry data already available, perimeter mapping may be conducted to update existing files.

Sampling Methods

Position and depth data for bathymetry mapping will be collected with a *Lowrance HDS-5 Lake Insight* sonar and GPS unit. The GPS will be set to use WGS 84 to be consistent with State of Alaska databases. Latitude and longitude will be recorded in degrees to the fifth decimal.

Data Collection

Data will be collected by first following the shoreline in a small skiff within 5 m of shore where adequate depth (>0.5 m) allows. When shallow water (<0.5 m) is encountered, we will move the skiff further away from shore until there is adequate depth (>0.5 m) and mark the section on the map. Where the 0.5 m contour deviates substantially from the shore, a GPS will be used to track these sections along the lake perimeter (by either walking the shore or near shore) and depth measurements will be documented where the fathometer is unable to take readings. After surveying the shoreline the rest of the lake will be surveyed along multiple circular transects, spaced equidistance apart, paralleling the shoreline and decreasing in size until the middle of the lake is reached (Figure 5).

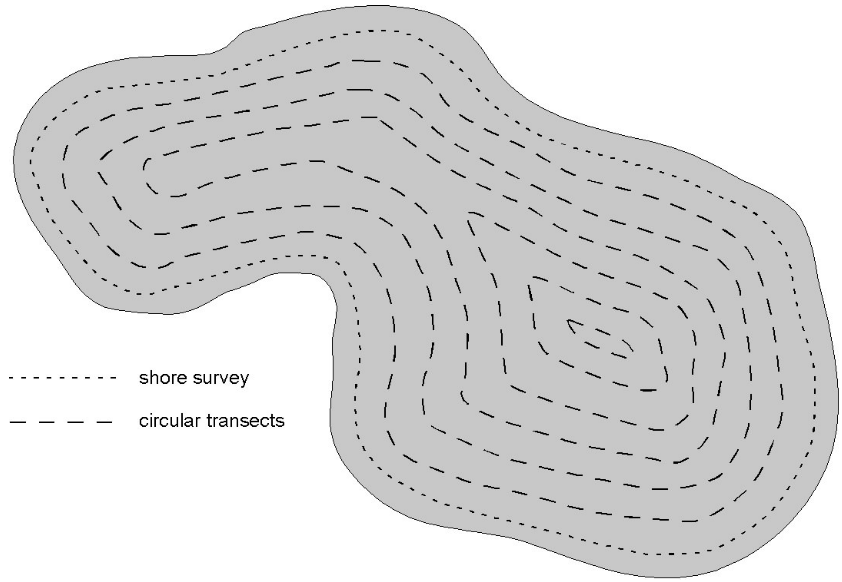


Figure 5.–Shore and circular transect pattern used to collect depth data in study lakes.

The number of transects will be determined by these guidelines: Lakes that are less than 40 ha will have a minimum of six transects; lakes between 40 and 200 ha will have a minimum of 10 transects; and, lakes that are 200 to 800 ha will a have a minimum of 15 transects. If the lake bottom appears to be highly variable or “interesting,” more transects will be added after the initial transects are complete. Position and depth data are recorded every 2 seconds. This is a general design and it will be modified to conform to different lakes.

The immediate surroundings (up to 5 m from shore) of the lake will be described through visual observations. This will include documenting inlets and outlets and noting the general vegetation cover as tundra, shrub (willow), deciduous, coniferous, or a combination of these types.

At each lake, a minimum of two digital photographs will be taken: One photograph taken from the south shore looking north, and one photograph taken from the north shore looking south. Additional photographs may be taken of notable habitat features or other subjects of interest at the lake. Aerial photographs (when possible) will be taken from an altitude of 300 m above the lake and cover the entire shoreline.

Data Reduction and Map Generation

Lake maps will be generated using *ArcMap 3D Spatial Analyst*. Surface area, mean depth, max depth, volume, max length, and shoreline length will also be calculated using ArcMap.

Bathymetric maps will be added to the Alaska Lake Database (ALDAT) (http://www.adfg.alaska.gov/index.cfm?adfg=fishingSportStockingHatcheries.lakesdatabase), used to update the Division of Sport Fish’s Lake Fishing Information webpage (http://www.adfg.alaska.gov/index.cfm?adfg=fishingSport.region), and made available to the public at Fairbanks, Delta, and Glennallen ADF&G offices.

SCHEDULE AND DELIVERABLES

Preliminary dates for sampling, data reduction and analysis, and reporting are summarized below. Results from lake evaluations will be summarized in a FDS report containing 2014–2016 data. A draft of this report will be submitted to the Research Supervisor by March 1, 2017. Water quality data and bathymetric maps resulting from lake surveys will be summarized and filed by lake at the Fairbanks Regional Office.

Stocked Fishery Population Assessments (SFP)

Dates	Activity
1 Mar–30 April 2014	Critical period for conducting dissolved oxygen surveys (as time permits). These data will be summarized and archived in a regional database.
12 May–20 June 2014	Spring lake sampling. Actual stop time will depend on water temperature and flight availability. Fisheries to sample: Bathing Beauty Pond, Big D Pond, Jan Lake, Parks Hwy 261, Tolsona Mountain Lake, and Z Pit
11 Aug–22 Aug 2014	Fall lake sampling. Actual start time will depend on water temperature. Fisheries to sample: Backdown Lake, Donnely Lake, Last Lake, Tex Smith Lake, and Two Mile Lake.
15 Nov 2014	Fish, water quality, and bathymetric data summary and analysis complete. Resulting data, maps, and photos uploaded to ADF&G websites and databases.
1 March 2017	Draft FDS report summarizing stocked fishery evaluations submitted to Research Supervisor.

New Lake Evaluations (SWG)/Ambler Road Lake Surveys (DOT)

Dates	Activity
1 Mar–30 April 2014	Critical period for conducting dissolved oxygen surveys (as time permits). These data will be summarized and archived in a regional database.
27 May–15 July 2014	Lake sampling. Actual sample times will depend on ice out and water temperature. Lakes to sample: 6 Ambler Road lakes (from AR1, AR2, AR4, AR5, Avaraart Lake, Birch Hill Lake, Kollioksak Lake, Norutak Lake, Nutuvuki Lake, and Tobuk Lake), Big D2 Pond, George Lake, Healy Lake, Seven Mile (Boulder) Lake, and Tanana Lake.
15 Nov 2014	Fish, water quality, and bathymetric data summary and analysis complete. Resulting data, maps, and photos uploaded to ADF&G websites and databases.
1 March 2017	Draft FDS report summarizing lake evaluations submitted to Research Supervisor.

RESPONSIBILITIES

Cal Skaugstad: Fishery Biologist III, Stocked Fisheries Program Supervisor.
Duties: Supervision of all aspects of projects in the Stocked Fisheries Program. Develop stocking plans for Region III and coordinate sampling schedules, data analysis, and report writing with project personnel. Supervise data analysis for stocked fishery population assessments in 2013, assist in field work, and co-author one FDS report (Management Objectives 1 and 2, Research Objectives 1 and 2).

April Behr: Fishery Biologist II, Stocked Fisheries Program Project Coordinator
Duties: Coordinate and lead lake sampling projects. Assign and supervise field crews, coordinate and supervise field data collection, conduct data analysis for fish population sampling, summarize water quality data, generate bathymetric maps, assist in field work, and co-author one FDS report (Management Objectives 1–4, Research Objectives 1–6).

Kelly Mansfield: Fishery Biologist I.
Duties: Supervise laboratory work. Assist with fish population data analysis, water quality data summaries, making bathymetric maps, and draft portions of one FDS report (Management Objectives 1–4, Research Objectives 1–6).

Jiaqi Huang: Biometrician II.
Duties: Provide biometric support for operational plans, data analysis, and FDS report review.

Virgil Davis: Technician III.
Duties: Field crew leader. Assist with field and laboratory work and data entry.

Chloe Johnson: Technician II.
Duties: Crew member. Assist with field and laboratory work and data entry.

Nancy Sisinyak: Information Officer II.
Duties: Disseminate information to the public through handouts, booklets, and the ADF&G web page.

REFERENCE CITED

Behr, A. E., J. T. Fish, and C. Skaugstad. 2005. Evaluation of rainbow trout in Lisa Lake during 2001, and fish population monitoring in stocked waters in the Tanana River and Copper River drainages, 1999-2003. Alaska Department of Fish and Game, Fishery Data Series No. 05-19, Anchorage.

Behr, A. and C, Skaugstad. 2006. Evaluation of Rainbow Trout in Koole Lake and Rainbow Lake, 2004. Alaska Department of Fish and Game, Fishery Data Series No. 06-39, Fairbanks.

Behr, A. and C. Skaugstad. 2007. Evaluation of stocked rainbow trout populations in Interior Alaska, 2005. Alaska Department of Fish and Game, Fishery Data Series No. 07-49, Anchorage.

Cochran, W. G. 1977. Sampling techniques, 3rd edition. John Wiley and Sons, New York.

Conover, W. J. 1980. Practical nonparametric statistics 2nd ed. John Wiley & Sons, New York.

Danylchuk, A. J. and W. M. Tonn. 2003. Natural disturbances and fish: local and regional influences on winterkill of fathead minnows in boreal lakes. Transactions of the American Fisheries Society 132:289-298

Doxey, M. 1989. Evaluation of stocked waters in the Tanana drainage, 1988. Alaska Department of Fish and Game, Fishery Data Series No. 106, Juneau.

Doxey, M. 1992. Abundance of rainbow trout in Birch and Quartz lakes, 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-10, Anchorage.

Fish, J. T., C. Skaugstad. 2004. Evaluation of Rainbow Trout in Quartz Lake, 2001 & 2002. Alaska Department of Fish and Game, Fishery Data Series No. 04-02, Anchorage.

Havens, A. C., M. Alexandersdottir, and S. Sonnichsen. 1992. Evaluation of rainbow trout populations in Big Lake, Alaska, 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-18, Anchorage.

Horak, D. L. and H. A. Tanner. 1964. The use of vertical gill nets in studying fish depth distribution, Horsetooth Reservoir, Colorado. Transactions of the American Fisheries Society 93:137-145.

Horne, A. J. and C. R. Goldman. 1994. Limnology, 2nd Edition. McGraw-Hill, Inc., New York.

Koenings, J. P., J. A. Edmundson, G. B. Kyle, and J. M. Edmundson. 1987. Limnology field and laboratory manual: methods for assessing aquatic production. Alaska Department of Fish and Game, Division of Fisheries Rehabilitation, Enhancement, and Development, No. 71.

Kwain, W. and R. W. McCauley. 1978. Effects of age and overhead illumination on temperatures preferred by underyearling rainbow trout, *Salmo gairdneri*, in a vertical temperature gradient. Journal of the Fisheries Research Board of Canada 35:1430-1433.

LaPerriere, J. D., T. D. Simpson and J. R. Jones. 2003a. Comparative limnology of lakes in Interior Alaska. Lake and Reserv. Manage. 19(2):122-132.

LaPerriere, J. D, J. R. Jones and D. K. Swanson. 2003b. Limnology of lakes in Gates of the Arctic National Park and Preserve, Alaska. Lake and Reserv. Manage. 19(2):108-121.

Overholtz, W. J., A. W. Fast, R. A. Tubb, and R. Miller. 1977. Hypolimnion oxygenation and its effects on the depth distribution of rainbow trout and gizzard shad. Transactions of the American Fisheries Society 106:371-375.

Rowe, D. K. 1984. Factors affecting the foods and feeding patterns of lake-dwelling rainbow trout in the North Island of New Zealand. New Zealand Journal of Marine and Freshwater Research 18:129-141.

Rowe, D. K. and B. L. Chisnall. 1995. Effects of oxygen, temperature and light gradients on the vertical distribution of rainbow trout, Oncorhynchus mykiss, in two North Island, New Zealand, lakes differing in trophic status. New Zealand Journal of Marine and Freshwater Research 29:421-434.

Seber, G. A. F. 1982. Estimation of animal abundance and related parameters. -2nd edition. Charles Griffin & Co Ltd.

Skaugstad, C. *In prep.* Fish Stocking Model to Create and Maintain Stocked Fisheries in Interior Alaska. Alaska Department of Fish and Game, Fishery Data Series, Anchorage.

REFERENCES CITED (CONTINUED)

Skaugstad, C. and J. Fish. 2002. Evaluation of stocked game fish in the Tanana Valley, 2000. Alaska Department of Fish and Game, Fishery Data Series No. 02-11, Anchorage.

Warner, E. J. and T. P. Quinn. 1995. Horizontal and vertical movements of telemetered rainbow trout (*Oncorhynchus mykiss*) in Lake Washington. Canadian Journal of Zoology 73:146-153.

Wetzel, R. G. 1975. Limnology. Saunders, Philadelphia.

Zar, J. H. 1984. Biostatistical Analysis, 2nd ed. Prentice-Hall Inc. Englewood Cliffs, NJ.

APPENDIX A

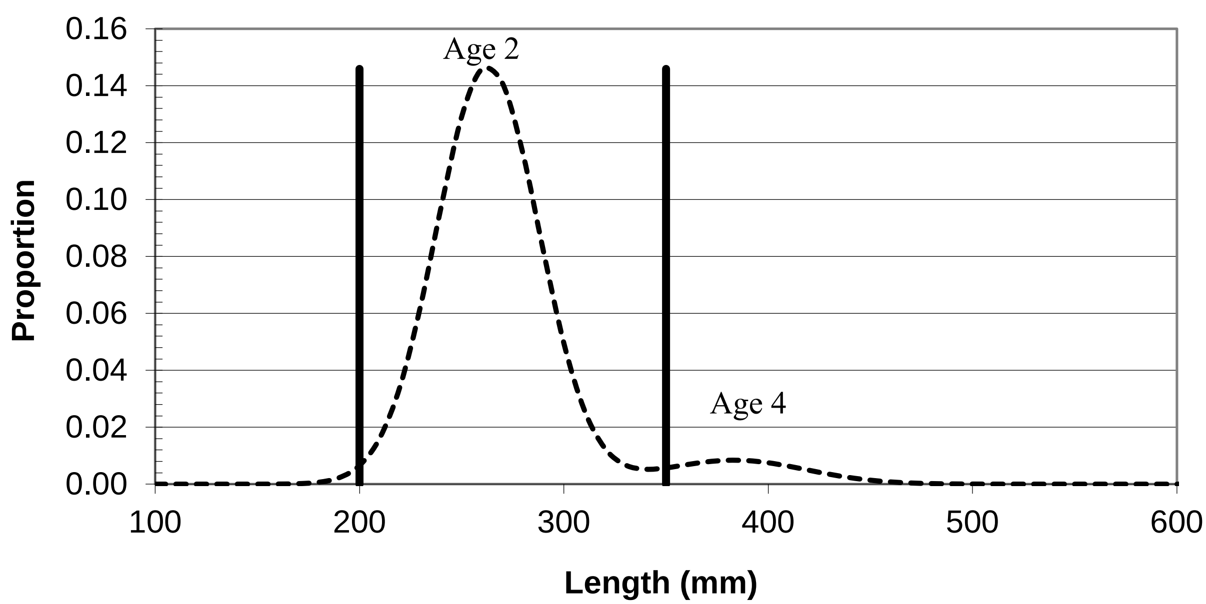
FISH POPULATION STRUCTURES BASED ON MANAGEMENT STOCKING SCHEMES

BACKDOWN LAKE – FALL SAMPLING

Surface Area:	2.09 hectares
Management Category:	Regional Management
Sub-Category:	Rural
Stocking Frequency:	Alternate years

Management objectives for mean length by defined length category for 2014. Mean length is based on a fall sampling date of 18 August 2014.

	200 mm ≤ RT <350 mm
Length (mm)	260



Backdown Lake. Modeled length distribution of rainbow trout by age cohort for 2014 using a preferred stocking scheme to achieve the lake management category objectives for size composition. Actual stockings are listed in Appendix B. Vertical lines indicate the length category between 200 mm and 350 mm fish for Regional Management.

-continued-

DONNELLY LAKE – FALL SAMPLING

Surface Area: 12.29 hectares

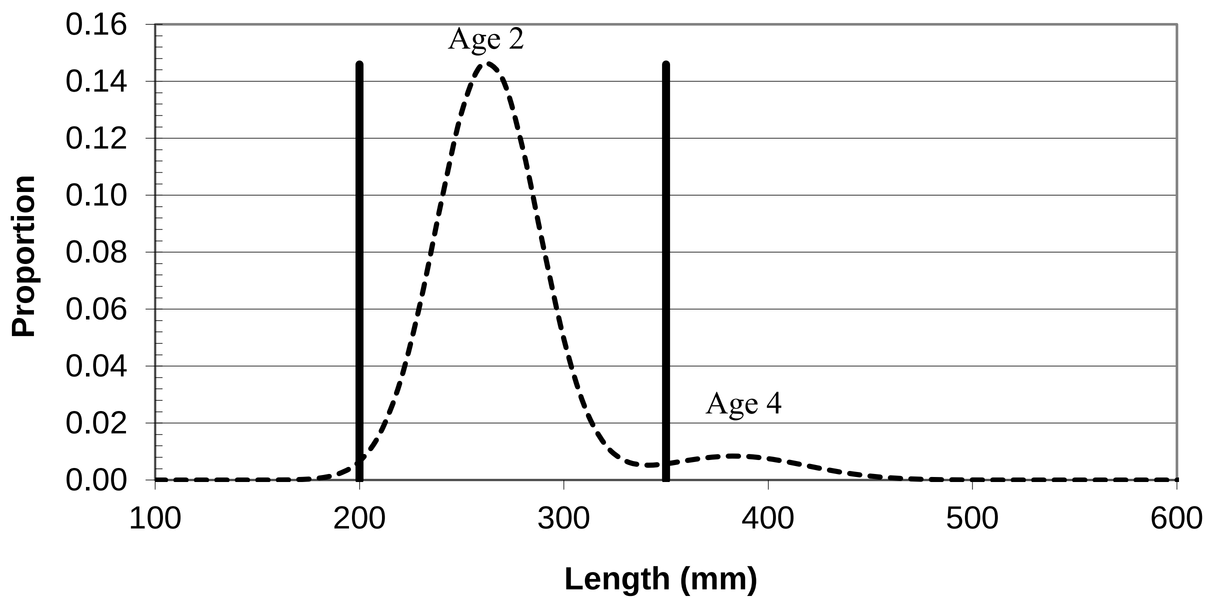
Management Category: Regional Management

Sub-Category: Rural

Stocking Frequency: Alternate years

Management objectives for mean length by defined length category for 2014. Mean length is based on a fall sampling date of 18 August 2014.

	200 mm ≤ RT <350 mm
Length (mm)	260



Donnelly Lake. Modeled length distribution of rainbow trout by age cohort for 2014 using a preferred stocking scheme to achieve the lake management category objectives for size composition. Actual stockings are listed in Appendix B. Vertical lines indicate the length category between 200 mm and 350 mm fish for Regional Management.

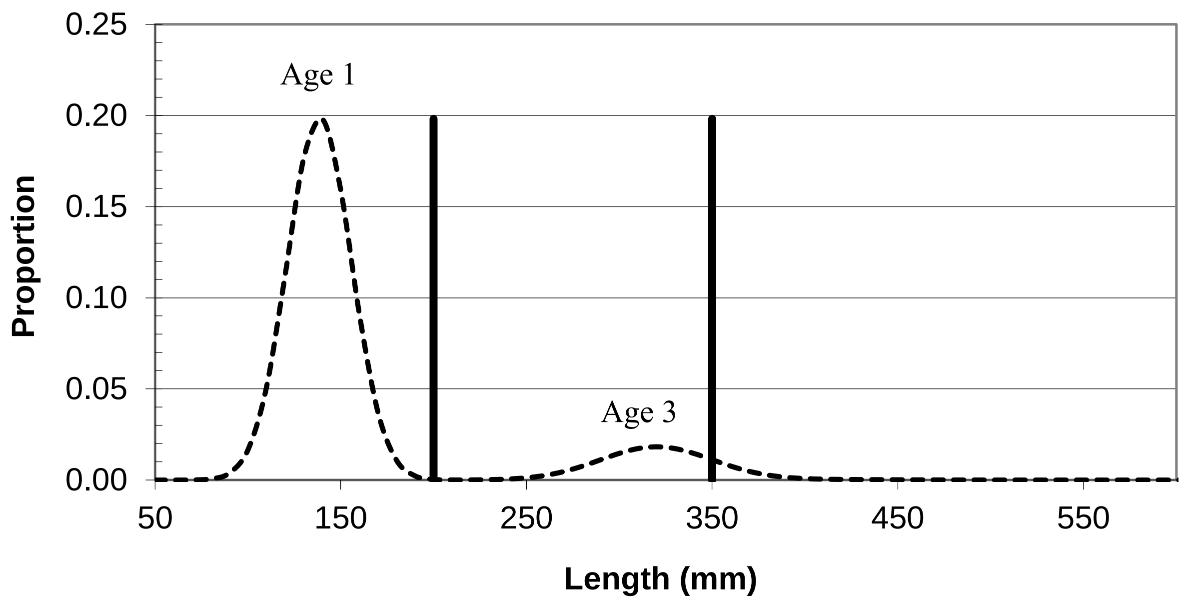
-continued-

TOLSONA MOUNTAIN LAKE – SPRING SAMPLING

Surface Area:	24.72 hectares
Management Category:	Regional Management
Sub-Category:	Remote
Stocking Frequency:	Alternate years

Management objectives for mean length by defined length category for 2014. Mean length is based on a spring sampling date of 16 June 2014.

	200 mm ≤ RT <350 mm
Length (mm)	308



Tolsona Mountain Lake. Modeled length distribution of rainbow trout by age cohort for 2014 using a preferred stocking scheme to achieve the lake management category objectives for size composition. Actual stockings are listed in Appendix B. Vertical lines indicate the length category between 200 mm and 350 mm fish for Regional Management.

APPENDIX B

STOCKING HISTORY (2008–2013) FOR LAKES TO BE SAMPLED IN 2014

Appendix B.–Stocking history (2008–2013) for lakes to be sampled in 2014.

Location	Date	Species	Average Length (mm)	Total
Backdown Lake	8/26/2008	RT	64	1,200
Backdown Lake	8/14/2009	AC	72	500
Backdown Lake	6/7/2010	RT	85	705
Backdown Lake	8/23/2011	AC	100	230
Backdown Lake	6/26/2012	RT	95	904
Backdown Lake	8/26/2013	AC	113	150
Bathing Beauty Pond	5/16/2008	RT	158	1,617
Bathing Beauty Pond	5/22/2008	RT	161	553
Bathing Beauty Pond	6/10/2008	RT	161	1,350
Bathing Beauty Pond	9/3/2008	AC	211	2,222
Bathing Beauty Pond	9/10/2008	KS	165	1,000
Bathing Beauty Pond	5/15/2009	RT	143	1,500
Bathing Beauty Pond	5/26/2009	RT	138	1,500
Bathing Beauty Pond	6/5/2009	AC	165	700
Bathing Beauty Pond	8/18/2009	KS	135	1,000
Bathing Beauty Pond	5/13/2010	RT	123	1,500
Bathing Beauty Pond	5/13/2010	AC	168	2,100
Bathing Beauty Pond	5/20/2010	RT	125	1,900
Bathing Beauty Pond	5/25/2010	RT	244	200
Bathing Beauty Pond	5/20/2011	AC	174	1,022
Bathing Beauty Pond	6/14/2011	RT	85	1,270
Bathing Beauty Pond	5/22/2012	RT	194	1,426
Bathing Beauty Pond	6/1/2012	AC	263	200
Bathing Beauty Pond	6/18/2012	RT	168	1,700
Bathing Beauty Pond	10/2/2012	KS	210	1,037
Bathing Beauty Pond	5/31/2013	RT	224	1,931
Bathing Beauty Pond	6/4/2013	AC	261	500
Bathing Beauty Pond	6/7/2013	RT	323	200
Bathing Beauty Pond	6/18/2013	RT	211	1,786
Bathing Beauty Pond	8/27/2013	GR	230	775
Bathing Beauty Pond	9/25/2013	KS	211	538
Big "D" Pond	6/12/2012	RT	187	1,089
Big "D" Pond	6/8/2013	RT	215	1,298
Big "D" Pond	6/19/2013	GR	222	350
Donnelly Lake	8/19/2008	RT	52	6,500
Donnelly Lake	6/7/2010	RT	85	4,400
Donnelly Lake	6/26/2012	RT	95	2,924

-continued-

Location	**Date**	**Species**	**Average Length (mm)**	**Total**
Jan Lake	8/12/2008	RT	47	4,000
Jan Lake	6/11/2009	SS	57	4,500
Jan Lake	8/10/2010	GR	57	2,001
Jan Lake	6/13/2013	KS	165	442
Last Lake	8/26/2008	AC	97	345
Last Lake	6/20/2012	RT	169	278
Last Lake	6/19/2013	RT	213	318
Parks Hwy 261	5/22/2008	RT	152	200
Parks Hwy 261	5/26/2009	RT	138	200
Parks Hwy 261	5/20/2010	RT	141	200
Tex Smith Lake	8/26/2009	RT	50	3,000
Tex Smith Lake	6/2/2011	RT	86	3,000
Tex Smith Lake	6/20/2012	RT	169	488
Tex Smith Lake	8/8/2012	RT	181	383
Tex Smith Lake	6/12/2013	RT	222	543
Tex Smith Lake	9/10/2013	RT	216	704
Tolsona Mountain Lake	8/26/2008	RT	55	14,200
Tolsona Mountain Lake	8/24/2010	RT	54	10,078
Tolsona Mountain Lake	9/10/2013	RT	73	8,500
Two Mile Lake	8/26/2009	RT	50	4,000
Two Mile Lake	6/2/2011	RT	86	4,259
Two Mile Lake	6/17/2013	RT	211	1,000
Two Mile Lake	9/10/2013	RT	216	1,001

AC=Arctic char *Salvelinus alpinus*
GR=Arctic grayling *Thymallus arcticus*
KS=Chinook salmon *Oncorhynchus tshawytscha*
LT=lake trout *Salvelinus namaycush*
RT=rainbow trout *Oncorhynchus mykiss*

APPENDIX C

FIELD DATA FORMS

Gear - Field Data Sheet

Alaska Department of Fish and Game
Division of Sport Fish – Stocked Fisheries Program

Lake Name: ____________________
Date: ____________________
Personnel: ____________________

Gear	Waypoint	Depth	Set	Pull	Water Temp (°C)

Gear Codes

FNn	fyke net	n	net number
TNn/s	tangle net*	s	set number
SG	sport gear		

*distinguish between floating (F) and sinking (S) nets

Waypoints
Save waypoints marking daily gear set locations in WGS 84 GPS datum (decimal degrees to the fifth decimal). Mark waypoints on a new bathymetric map each day.

Depth
Measure the water depth (m or ft) at each set location using a hand held depth instrument.

Set and Pull Time
Record date (MM/DD) and time (military time) for each gear set and pull.

Temperature
When each net is SET record water temperature (to the nearest 0.10°C) 1 m below the surface at each set location.

-continued-

Fish - Field Data Sheet

Alaska Department of Fish and Game
Division of Sport Fish – Stocked Fisheries Program

Lake Name: ______________________________
Date: ______________________________
Personnel: ______________________________

Gear	WP	Species	Length	M	T	D	P

Gear	WP	Species	Length	M	T	D	P

Gear Codes

FNn fyke net
HNn hoop net
TNn/s tangle net *
SG sport gear

n net number
s set number

*distinguish between floating (F) and sinking (S) nets

WP=way point in WGS 84 GPS datum (ddd.ddddd)
Length= measured FL to nearest millimeter

Species Codes

RT rainbow trout
SS silver salmon
AC Arctic char
KS king salmon
BB burbot
GR Arctic grayling

Species not given a code will be written out.

M=Recapture (marked); **T**=thin; **D**=disease; **P**=parasite: Leave blank if no signs exist. For D or P provide brief description.

-continued-

Water Quality - Field Data Sheet

Alaska Department of Fish and Game
Division of Sport Fish – Stocked Fisheries Program

Location: ______________________ **Station #:** ________ **Way Point:** _________
Date: ______________________ **Time:** ______________________
Personnel: ____

Weather/Cloud Cover: ____
Air Temperature (°C): ______________________ **Secchi Depth:** **Disappear (m):** ____________
Snow Cover (cm): ______________________ **Reappear (m):** ____________
Ice Thickness (cm): ______________________ **Alkalinity Sample Time:** ____________

Depth (M)	**Bar Pres**	**Temp C**	**D.O.**	**%D.O.**	**SP Cond**	**pH**	**TDS**	**ORP**
0								
0.5								
1								
1.5								
2								
2.5								
3								
3.5								
4								
4.5								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
Max Depth								

Lake Type
_____ glacial
_____ organically stained
_____ clear-water

Water Color
______ clear
______ ferric
______ glacial-high turbidity
______ glacial-low turbidity
______ humic
______ muddy

Pictures (at least 2; mark when done)
_______ From South Shore
_______ From North Shore
_______ Trails (if any)

Notes:

APPENDIX D

ASSUMPTIONS AND BIAS

An accurate estimate of a population length frequency distribution requires that all fish in a population have the same probability of capture. In practice this likely does not happen and this assumption cannot be evaluated with a single-sample capture-event. However, a review of the literature and previous mark recapture studies conducted by ADF&G indicates that potential bias may be minimized by avoiding sampling activities when water temperatures are high, by sampling different habitat areas, and by using gear that is not size selective.

Researchers have found that water temperature influences rainbow trout distribution in lake systems, and have documented movement of rainbow trout from nearshore to offshore habitats when water temperature exceeds 20°C (Horak and Tanner 1964; Overholtz et al. 1977; Rowe and Chisnall 1995; Rowe 1984). Doxey (1989, 1992; M. Doxey, Sport Fish Biologist, Retired, ADF&G, Fairbanks; personnel communication) noted an influx of rainbow trout to shallow, nearshore areas as water temperature dropped during fall sampling activities conducted at Birch Lake, Alaska. Researchers have also noted that rainbow trout preferred depths of 0-4 m in the spring, and avoided shallow water as temperature increased throughout the summer (Overholtz et al. 1977). Additionally, a study conducted by Kwain and McCauley (1978) found that older rainbow trout have a lower temperature preference than do younger fish. Based on these findings, we conclude that larger fish will likely be the first to seek thermal refuge offshore as water temperature in littoral areas increases. To minimize the potential for size bias sampling due to this phenomenon, all sampling during our study will be conducted when water temperature 1 m beneath the surface is < 18°C.

Although we expect rainbow trout populations to be distributed nearshore when water temperature is < 18°C, we will sample both nearshore and offshore habitats to verify the presence or absence of fish in both areas. Previous studies conducted by ADF&G (under similar thermal conditions) found that capture rates for rainbow trout in offshore tangle nets, fyke nets, and hoop traps were lower than those for nearshore fyke nets (Fish and Skaugstad 2004; Havens et al. 1992; Behr and Skaugstad 2007). Warner and Quinn (1995) found that radio-tagged rainbow trout in Lake Washington were predominantly found in nearshore areas and resided in the top 3 m of the water column 90% of the time during sampling conducted in June, August, September, and October. Similarly, approximately 88% of all rainbow trout caught during sampling activities in 2005 were captured in nearshore fyke nets (Behr and Skaugstad 2007).

To minimize the potential for size bias due to capture gear we will use fyke nets and 13 mm bar, fine thread, monofilament tangle nets during our study. Fyke nets are typically fished in shallow waters and have proven effective at catching rainbow trout 50mm to 600 mm (Behr and Skaugstad 2006; Fish and Skaugstad 2004). The length of fish captured in tangle nets is variable and depends on mesh size; however, a 13 mm mesh should be sufficient to capture age-1 and older fish in stocked lakes.

The sampling methods used in this study are similar to those used in previous two-sample mark-recapture experiments conducted by ADF&G in which size bias was examined using either Kolmogorov-Smirnov (K-S) tests (Conover 1980) or chi-square contingency table analysis (Seber 1982). Robust and objective evaluation of size biased sampling is problematic, at best, when fish grow between sampling events. In Interior Alaska, average growth rates of nearly 1 mm per day have been observed for rainbow trout during summer (Doxey 1989).

-continued-

We reviewed several previous experiments to evaluate the relation between detected size bias during rainbow trout sampling and water temperature. In two-sample experiments where a hiatus of more than two weeks occurred between sampling events (allowing for substantial growth), we reanalyzed experimental data using methods described in Behr and Skaugstad (2006), where unambiguous testing for size bias could only be conducted for first event sampling. In other experiments, where necessary, data were reanalyzed to test for size bias during both sampling events using methods described in Behr et al. (2005). These results may differ from published results in some cases, as we analyzed size data from all rainbow trout captured during these experiments, not just the target age classes.

In 2004, two mark-recapture experiments were conducted at Koole and Rainbow lakes to estimate the abundance of rainbow trout. Sampling procedures for both experiments were similar to those for this study, except that hook-and-line gear was used to supplement catches at both lakes and hoop nets were used at Rainbow Lake. K-S test results indicated that no significant size bias occurred during the first sampling event at Koole Lake, where the maximum water temperature recorded was 14°C at a depth of 0.3m during June 7–11. Similarly, no significant size bias was detected for the first sampling event at Rainbow Lake where the highest water temperature recorded was 17.7°C at a depth of 0.5m on August 25 (Behr and Skaugstad 2006). During Events 1 and 2, 97% and 99% of samples, respectively, were caught in fyke traps. Age-0 rainbow trout that were stocked in Rainbow Lake prior to sampling and subsequently captured in fyke nets were not used in mark-recapture experiment. Usually the smallest age-0 fish can escape through the fyke net mesh and they are subject to predation by larger fish in the fyke nets. This situation will likely result in an observed probability of capture that is significantly different from that for the other age cohorts. Consequently, age-0 fish are enumerated and measured during population sampling but the data are not used to generate information about population structure.

Only near shore fyke nets were used during a two-sample mark-recapture experiment conducted in mid-June and mid-August of 2001 at Lisa Lake. K-S test results indicated that size bias for rainbow trout captured during the first event was not significant (Behr et al. 2005). Water temperature during mid-June was 17.5°C 1 m beneath the surface. In September and October of 2006 a second mark-recapture experiment was performed at Lisa Lake. Offshore tangle nets and nearshore fyke nets were used during both events, and K-S test results indicated that no significant size bias occurred (Behr and Skaugstad 2007). Water temperatures at 1 m beneath the surface were 11.1°C during Event 1 and 5.5° during Event 2.

In 2000, four two-sample mark-recapture experiments were conducted at Dune, Bluff Cabin, Donna, and Little Donna lakes (Skaugstad and Fish 2002). Fyke nets, tangle nets, and hook-and-line gear were used. Sampling was conducted in June and August. Reanalysis of rainbow trout mark-recapture data for Dune Lake provided no significant evidence of size bias sampling during Event 1 ($p = 0.972$) where the water temperature was 16.3°C at a depth of 1.0 m on June 15 (the last day of sampling). Reanalysis of Donna Lake data provided no significant evidence of size bias sampling during either Event 1 ($p = 0.196$) or Event 2 ($p = 0.772$). Water temperature was

-continued-

about 10.5°C at a depth of 1 m on August 31 (first day of Event 2 sampling). Similar results were obtained from data from Little Donna Lake for both Event 1 ($p = 0.425$) and Event 2 ($p = 0.978$).While sampling at Little Donna Lake occurred during the same time frame as at Donna Lake, no water temperature data were available. In contrast, reanalysis of Bluff Cabin Lake data indicated significant size bias sampling during both Event 1 ($p < 0.001$) and Event 2 ($p = 0.001$) where the water temperature was 17.2°C at a depth of 1.0 m and 18.6°C at a depth of 0.5 m on 6 June (the first day of sampling).

Two-sample mark-recapture experiments were performed at Quartz Lake in 2001 to estimate the abundance of age-1 rainbow trout and in 2002 to estimate the abundance of age-2 and older rainbow trout (Fish and Skaugstad 2004). Nearshore and offshore fyke nets, hoop nets, and tangle nets were used in 2001 and sampling was conducted May 29 to June 1 (Event 1) and June 18 to 22 (Event 2). Reanalysis of these data indicated significant size bias sampling during both Event 1 ($p < 0.001$) and Event 2 ($p < 0.001$) where the water temperature was 11°C at a depth of 1 m on May 31 and 20°C at a depth of 1 m on June 22. Less than 1% of the rainbow trout were caught in floating fyke nets, hoop nets, and tangle nets deployed in water > 1 m in depth. In 2002, fyke nets and tangle nets were used and sampling was conducted in September. Re-analysis provided no significant evidence of size bias sampling during either Event 1 ($p = 0.384$) or Event 2 ($p = 0.493$). Water temperature was not recorded during sampling but typically lake temperatures have cooled to < 14°C by September. Rainbow Lake (16 km from Quartz Lake) was < 12°C 1 m below the surface in mid-September. During Event 1 no rainbow trout were caught in tangle nets in deep water and during Event 2 sixteen percent of the fish sampled were caught in tangle nets. The size distributions of fish captured with all gear types during Event 1 and Event 2 were not statistically different ($p = 0.734$).

Of the studies reviewed, only one result was inconsistent with our prescription to restrict sampling to when water temperature is < 18°C in order to minimize potential for size biased sampling of rainbow trout. Significant size bias sampling was detected during Event 1 sampling at Quartz Lake in 2001, when water temperatures was 11°C. Probability of capture of rainbow trout 170 mm and larger (age 2 and older) was greater than that of smaller rainbow trout (age-1). During Event 1 the larger rainbow trout were concentrated in a few nearshore areas for spawning and later, during the hiatus and Event 2, dispersed throughout the lake (Fish and Skaugstad 2004). Researchers realized that spawning behavior in spring would likely affect the capture probability of age-2 and older rainbow trout during the course of the study; however, they were interested only in estimating the abundance of age-1 rainbow trout. Future studies of the Quartz Lake rainbow trout population using single-sample methods to estimate relative abundance should be conducted in fall to avoid capture heterogeneity between different size/age cohorts.

Detecting capture heterogeneity when sampling small populations (< 2,000 fish) is very difficult. The K-S test is typically used during two-sample mark-recapture experiments to detect size bias sampling during either sampling event and to guide model selection for estimating abundance and composition. To estimate the power of the K-S test to detect size bias sampling in small populations, we constructed artificial populations of two age classes (age-1 and 2) of rainbow trout based on length-at-age data from previous experiments (ADF&G spreadsheet available from the authors). Population size varied from 500 to 2,000 fish, and within each population the

-continued-

proportion of age-2 fish was varied from 20% to 66%. We then simulated two-event mark-recapture sampling on these populations with sufficient sampling intensity to estimate abundance within 20% of the true value 95% of the time (assuming no size bias during sampling). We simulated probability of capture for age-2 fish to be 50% of the probability of capture of age-1 fish during both sampling events, and also simulated this size bias sampling during only Event 1 with no size bias during Event 2. We conducted K-S tests to detect capture heterogeneity and estimated power by evaluating the frequency when size bias sampling was concluded. The results from capture heterogeneity during both events and during Event 1 are reported in Table 5 and Table 6, respectively. When capture heterogeneity was simulated during both sampling events, the power of the K-S tests was poor (< 1% to 30%) when the segment of the population with lower capture probability comprised 50% or less of the population when using $\alpha = 0.05$ as the rejection criteria for the test. When $\alpha = 0.20$ was used as the rejection criteria, power was still poor (< 1% to 26%) when the segment of the population with lower capture probability comprised 33% or less of the population. In simulations where capture heterogeneity occurred only during Event 1, the power of the K-S test was poor (< 1% to 29%) when the segment of the population with lower capture probability comprised 33% or less of the population when using $\alpha = 0.05$ as the rejection criteria. When $\alpha = 0.20$ was used as the rejection criteria, power was still poor (< 9% to 23%) when the segment of the population with lower capture probability comprised 20% or less of the population.

The levels of capture heterogeneity sufficient to cause concern when interpreting composition proportions (detecting large fish 50% as often as smaller fish) are not likely to be detected during reasonably well designed two-sample experiments on small populations with age structures similar to what are usually encountered. The fairly poor power of widely used diagnostics tests under these conditions emphasizes the need to identify the field conditions where the chances of size bias sampling occurring can be minimized.

For our studies, the bias introduced by unequal capture probabilities for the different length-age cohorts has different effects on estimating length frequency mode location and mode amplitude. Mode location is important for determining the mean length of length-age cohorts while mode amplitude is important for determining the relative abundance of the length-age cohorts in the population. The bias caused by unequal capture probabilities when estimating mode location will be minimal when individuals in each length-age cohort have the same capture probability (i.e., capture probabilities are the same within cohorts but may be different between cohorts).

Bias will likely have a greater influence on estimating mode amplitude and, thus, on estimating proportions of fish in different length-age categories (i.e., relative abundance). As such, analysis of relative abundance is no longer performed; however, this bias could still affect mean values within specified length categories because multiple age cohorts are often present in a specified length category. Different capture probabilities between length-age cohorts will result in catches that are not representative of cohort abundance in the population. Increasing the sample size will make the modes more prominent but it will not improve the accuracy of the estimate. However, our review of other studies has shown that the likelihood of size bias is low when sampling is restricted to periods when water temperature is < 18°C. It is anticipated that two-sample mark-

-continued-

recapture studies will be conducted periodically for the larger lakes that are stocked on an annual basis and support a number of age cohorts. We will continue to use information from these studies to evaluate potential size bias associated with single-capture sampling.

Table 5.–Power of Kolmogorov-Smirnov (K-S) test to detect capture heterogeneity in small populations during two-sample mark-recapture studies designed to estimate true abundance within 20% of the true value 95% of the time, where ***x***% of the population has 50% of the capture probability of the remainder of the population during both sampling events. Results based on 10,000 simulations of two age classes of fish with adjacent but non-overlapping bell shaped length distributions and ***x***% represents one entire age class.

		Mean		Power of RvC & MvC K-S tests		
N	***x*%**	**M & C**	**R**	$\alpha = 0.05$	$\alpha = 0.10$	$\alpha = 0.20$
500	0.20	157	52	<0.01	<0.01	0.02
750	0.20	204	58	<0.01	<0.01	0.03
1,000	0.20	245	63	<0.01	0.01	0.04
1,500	0.20	313	69	<0.01	0.02	0.05
2,000	0.20	372	73	<0.01	0.02	0.06
500	0.33	158	54	<0.01	0.03	0.08
750	0.33	205	60	0.02	0.05	0.13
1,000	0.33	244	64	0.02	0.06	0.16
1,500	0.33	313	71	0.03	0.09	0.21
2,000	0.33	373	75	0.05	0.12	0.26
500	0.50	157	55	0.08	0.19	0.37
750	0.50	204	62	0.14	0.27	0.46
1,000	0.50	244	66	0.19	0.33	0.53
1,500	0.50	313	73	0.26	0.42	0.61
2,000	0.50	371	76	0.30	0.46	0.65
500	0.66	157	56	0.26	0.43	0.61
750	0.66	205	63	0.36	0.53	0.70
1,000	0.66	245	67	0.44	0.61	0.76
1,500	0.66	314	74	0.54	0.69	0.81
2,000	0.66	372	78	0.59	0.73	0.84

-continued-

Table 6.–Power of Kolmogorov-Smirnov (K-S) test to detect capture heterogeneity in small populations during two-sample mark-recapture studies designed to estimate true abundance within 20% of the true value 95% of the time, where ***x***% of the population has 50% of the capture probability of the remainder of the population during first event sampling and no capture heterogeneity occurs during second event sampling. Results based on 10,000 simulations of two age classes of fish with adjacent but non-overlapping bell shaped length distributions and *x*% represents one entire age class.

		Mean		**Power of RvC K-S test**		
N	***x*%**	**M & C**	**R**	$\alpha = 0.05$	$\alpha = 0.10$	$\alpha = 0.20$
500	0.20	157	49	<0.01	0.03	0.09
750	0.20	204	56	0.01	0.04	0.13
1,000	0.20	245	60	0.02	0.06	0.16
1,500	0.20	313	65	0.03	0.09	0.21
2,000	0.20	373	69	0.04	0.11	0.23
500	0.33	158	50	0.08	0.18	0.35
750	0.33	205	56	0.12	0.25	0.43
1,000	0.33	244	59	0.17	0.32	0.49
1,500	0.33	313	65	0.24	0.39	0.57
2,000	0.33	373	70	0.29	0.44	0.61
500	0.50	157	49	0.24	0.39	0.57
750	0.50	204	55	0.34	0.49	0.67
1,000	0.50	244	60	0.40	0.55	0.71
1,500	0.50	313	65	0.48	0.63	0.77
2,000	0.50	371	69	0.53	0.67	0.80
500	0.66	158	50	0.24	0.39	0.57
750	0.66	204	56	0.34	0.50	0.66
1,000	0.66	244	60	0.39	0.55	0.70
1,500	0.66	314	65	0.48	0.63	0.77
2,000	0.66	372	69	0.53	0.67	0.80